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O-13

Scanning and Full Field X-Ray Fluorescence Imaging with Laboratory X-ray Source

Kouichi Tsuji,* Momotaro Nakanishi, Ryouta Ozeki, and Tsugufumi Matsuyama
Graduate School of Engineering, Osaka City University (OCU), 3-3-138 Sugimoto, Sumiyoshi, Osaka 558-8585, Japan
*corresponding author's e-mail: tsuji@a-chem.eng.osaka-cu.ac.jp

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Many applications of x-ray fluorescence (XRF) analysis have been reported in various fields, such as in the environmental, archeological, biological, and forensic sciences as well as in industry. Elemental analysis near surface region is performed by XRF. Advanced x-ray focusing optics such as polycapillary optics enables a micro x-ray beam with a laboratory x-ray source, leading to micro-XRF analysis and scanning-mode XRF imaging. A confocal micro-XRF technique has been applied for the visualization of elemental distributions inside the samples. In parallel, the authors have studied a wavelength dispersive XRF (WDXRF) imaging spectrometer for a fast elemental imaging. A full-field energy dispersive X-ray fluorescence (FF-EDXRF) imaging spectrometer using single photon counting analysis with x-ray camera was also studied. We evaluated and discussed the performance of laboratory-made these scanning- and FF-imaging spectrometers concerning energy resolution, spatial resolution, quantitative performance and elemental imaging. At the end, compressed sensing which is one of general information processing technique was applied for high-resolution XRF images.

1. Introduction

X-ray fluorescence (XRF) is a non-destructive and non-contact elemental analysis method. XRF imaging gives us useful information near surface of the sample. XRF imaging can be achieved by scanning and projection method [1]. In the scanning method, an x-ray micro beam is created by using x-ray focusing optics. The sample is scanned to the x-ray micro beam and XRF images are constructed. In the projection type XRF imaging, the primary x-rays are irradiated to the large area of the sample. The emitted XRF from the sample is detected by 2D x-ray detector. To identify the energy of x-rays in the projection type, we have studied two approaches: (1) wavelength dispersive XRF imaging, (2) energy dispersive XRF imaging by single photon counting analysis. After introduction of these techniques, some applications are shown.

2. Confocal micro-XRF in the laboratory

The idea of confocal micro-XRF was proposed in the paper [2]. The first setup was reported in the cited paper [3]. Two polycapillary optics were applied for the creation of a micro primary x-ray beam and detection of XRF emitted from the sample. The two foci of the polycapillary lens were adjusted to a common position, which is termed the confocal point.

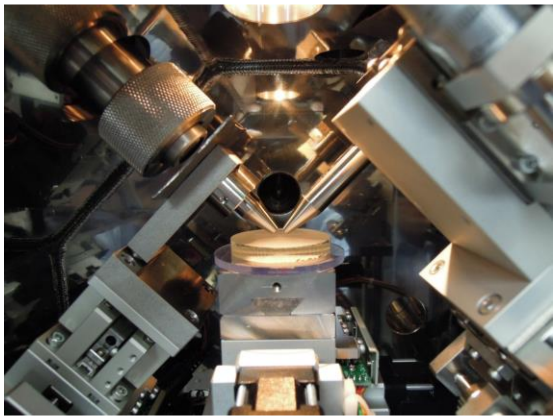

Fig. 1 Photograph of sample, polycapillary optics of confocal micro XRF instrument at OCU.

Figure 1 shows a laboratory-made confocal micro XRF (CM-XRF) setup at OCU. This CM-XRF instrument has a vacuum chamber; therefore, good sensitivities for low-Z elements were obtained [4].

CM-XRF offers unique XRF imaging modes shown in Fig. 2. Chemical reactions such as corrosion and deposition occur on the surface of the solid samples in solution. This process was monitored with a special solution cell by using another CM-XRF instrument which worked at ambient air pressure. One of the drawbacks of the scanning XRF imaging is a long acquisition time depending on analyzed area. Therefore, we have studied a fast imaging technique with fly-scan mode instead of step scan mode.

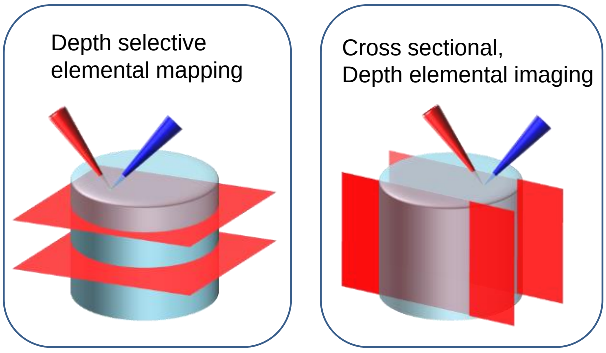

Fig. 2 Depth selective elemental XRF imaging (left) and cross section depth elemental XRF imaging (right) by CM-XRF.

3. Full field XRF imaging with 2D detector

3.1 WD-XRF imaging spectrometer

A WD-XRF imaging spectrometer was developed for elemental imaging by using a analyzing crystal such as LiF(200), as shown in Fig. 3 [5]. A straight type polycapillary optics was used for two dimensionally collimating the x-rays. It was demonstrated that a fast XRF imaging was possible for metal samples with an exposure time of 1 s or less.

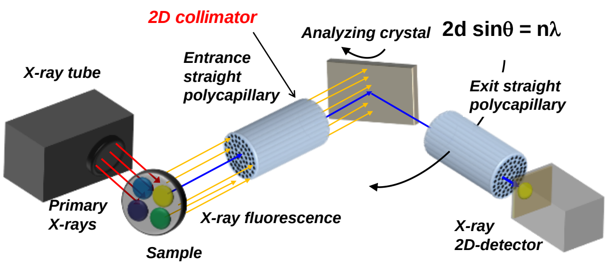

Fig. 3 WDXRF imaging spectrometer.

3.2 FF-EDXRF imaging spectrometer

Figure 4 shows experimental setup of the Full Field-EDXRF (FF-EDXRF) imaging spectrometer [6]. The exposure time was varied by the x-ray shutter. A straight polycapillary was installed in front of the CCD x-ray camera to keep the position information of x-ray fluorescence emitted from the sample. To obtain the XRF elemental images, a single photon counting

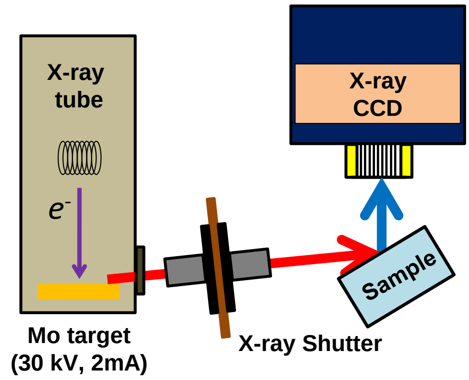

Fig. 4 Full field XRF imaging spectrometer.

analysis was applied. A part of the print circuit board sample was measured. Multiple elemental images of Cu, Br, Ti, Pb, Sn etc. were simultaneously obtained.

3.3 Compressed sensing

Compressed sensing is a technique of restoring target signals from a few observations. This technique was applied for FF-EDXRF imaging to improve the image resolution. We used the discrete cosine transform matrix as a dictionary matrix and Fast Iterative Shrinkage Thresholding Algorithm (FISTA) as an algorism for compression sensing analysis. The resolution of the Ti image obtained for the print circuit board sample by FF-EDXRF was improved [6].

4. Conclusions

Several XRF imaging techniques studied in the author's laboratory were discussed. Each imaging technique has advantages and drawbacks. It is important to apply such XRF imaging technique depending on the samples, experimental situations and demands.

5. References

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